Brighter Booster / Proton Driver Project

- Recognized that proton booster is a critical component for Fermilab
  - May be "the" key component for a high intensity program
- 2-year "real" machine study just completed
  - Shows that 16 GeV rapid-cycling design feasible
  - Designed to make minimal impact on on-going program
  - Initial cost estimate

Next step:

- Need to understand how new booster would fit into the program
  - What are the realizable intensities for the booster, MI, pbar, Tevatron?
  - With these intensity capabilities, what is the possible/best/optimized physics program.

Bottom line is always physics:

How will a Brighter Booster improve the Fermilab physics program over the next decade?

Physics Potential of a Brighter Booster

- What does the "Brighter Booster" offer?
  - Factor of 3 to 4 higher Main Injector intensity
    - Can run both fixed-target 120 and NuMI/Minos programs
      $\Rightarrow$ Need > 6×10^{13} protons per cycle
    - NuMI and BooNE could run with much higher intensity
  - Higher intensity will allow collider pbar production to be less sensitive to fixed-target 120 and neutrino running
    - Currently, NuMI 25% luminosity reduction
      Future, fixed-target 120 would give a 50% luminosity reduction
  - Higher intensity MI pulses on the pbar target would give increased pbar production and with a new accumulator, higher collider luminosity.
    - Could increase CDF/D0 luminosity by $\times 2$ to $\times 4$ $\Rightarrow$ But when?
    - Question: What limits the luminosity if booster intensity increased
  - "Brighter Booster" could be the front-end for a low-energy, high intensity muon /pion facility
    - Low energy pion and muon beams for experimentation
    - Muon cooling experiments moving towards a first muon storage ring

Upgraded Neutrino Oscillation Program

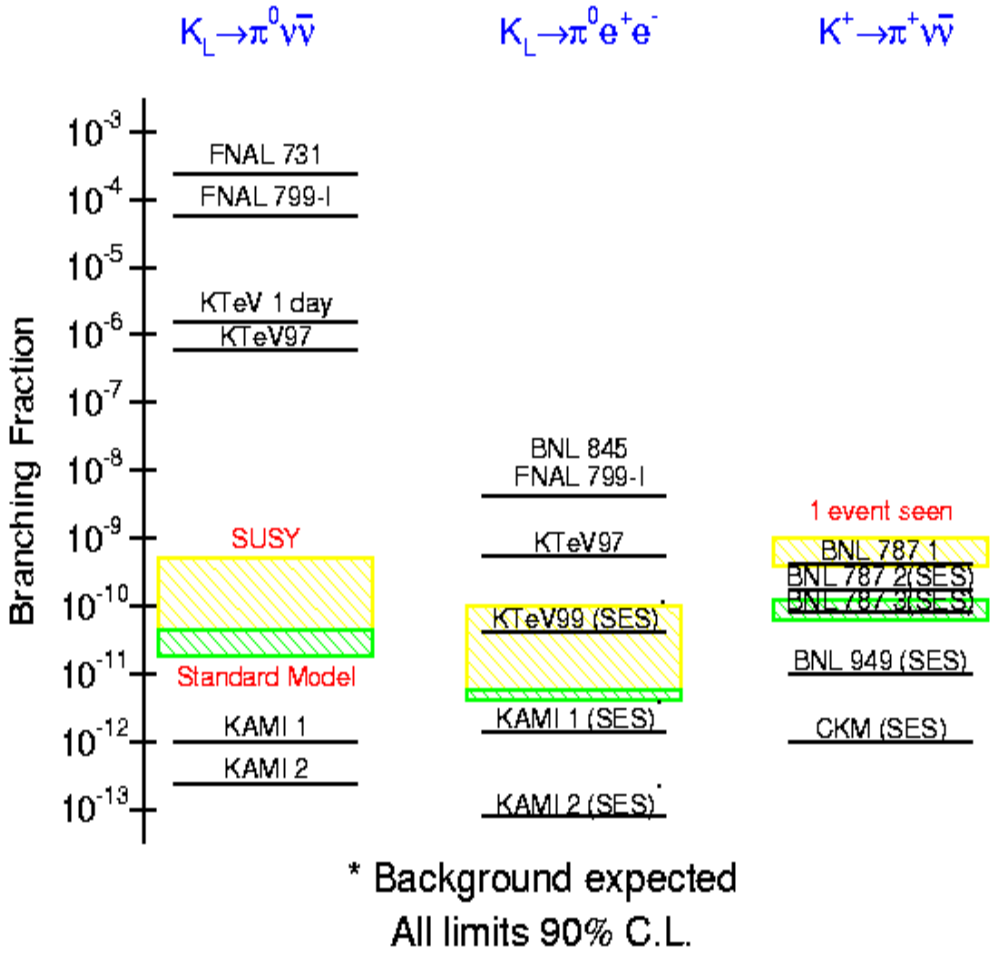
- Higher intensity for BooNE and Minos
  - Minos may be able to measure $\nu_{\mu,} \rightarrow \nu_e$ and $\sin^2 2\theta_{13}$
- Possible ν_τ appearance experiments
  - Short (20km) baseline experiment if MiniBooNE sees a signal
  - Emulsion-type experiment in Soudan becomes much more feasible
- Very long baseline experiment from Fermilab to SLAC/LBNL
  - Sensitivity to $\sin^2 2\theta_{13}$ through $\nu_{\mu,} \rightarrow \nu_e$
    - Probably systematics limited at about the 0.01 level
  - Is it possible to detect matter effects?
    - Measure the sign of $\Delta m_{23}^2 \Rightarrow$ Is m_3^2 bigger than m_2^3 ?

MI Fixed Target 120 GeV Program

- Kaon Program:
  - KAMI
    $K_L \rightarrow \pi^0 \nu \bar{\nu}$
  - CKM
    $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

- Other fixed-target experiments probing nucleon structure and particle production

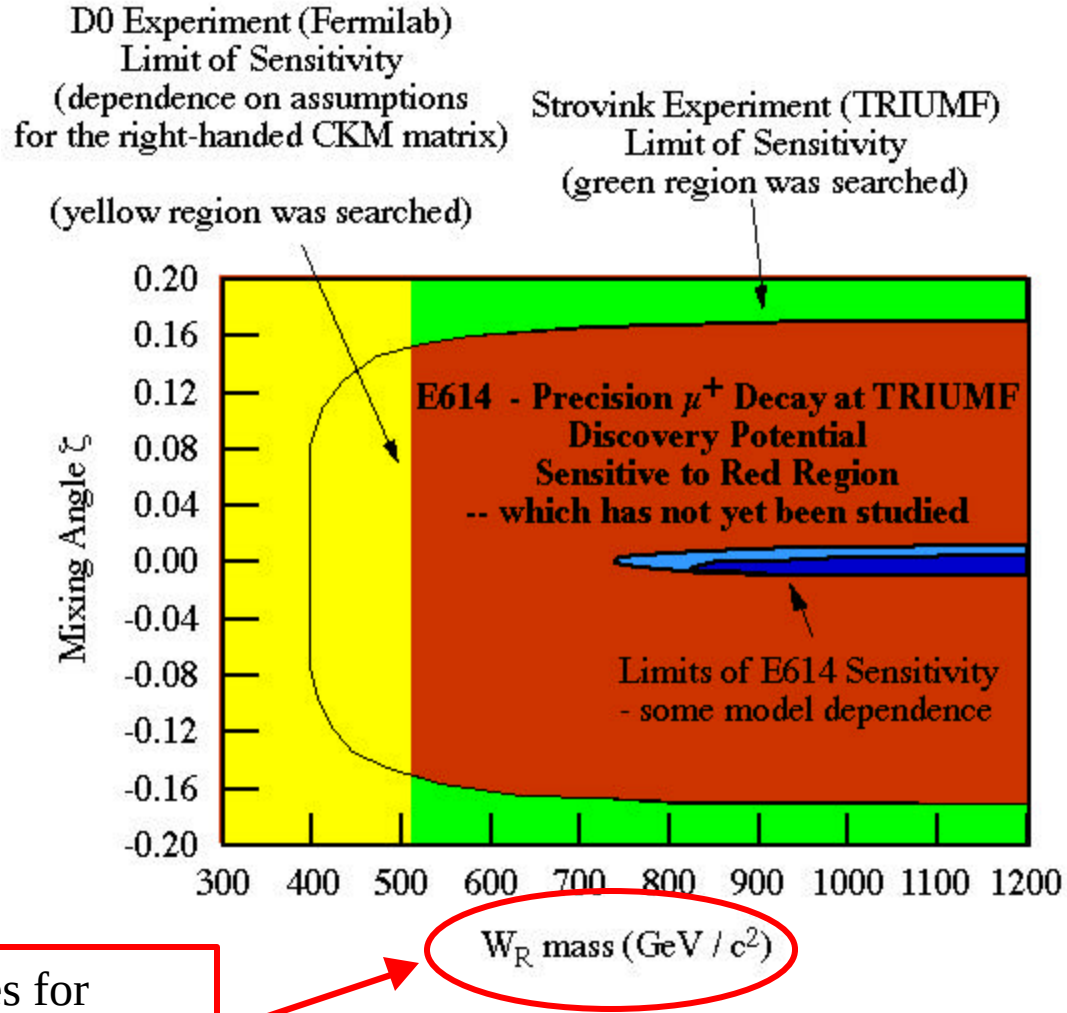
Intensity will be at a premium with current MI intensity



Low Energy Pion/Muon Facility

- Low Energy Experiments Can Also Probe High Mass
  - For example: New "Michel Parameters" experiment at TRIUMF
    - For $\mu^+ \rightarrow e^+ \nu_\mu \bar{\nu}_e$, measure energy and angle distribution to 1 part in 10^4

    $\Rightarrow$Measure the "Michel" parameters ρ, δ, ξ, and η with a precision 3 to 10 times better than previous.



Probe masses for right-handed W_R to ~1 TeV

Some Topics for Brighter Booster Physics Study

- Neutrino oscillations
  - Investigate the capabilities using the higher intensity available with a new booster for:

    1) An upgraded NuMI/Minos experiment with 3-4 times the intensity and an upgraded detector

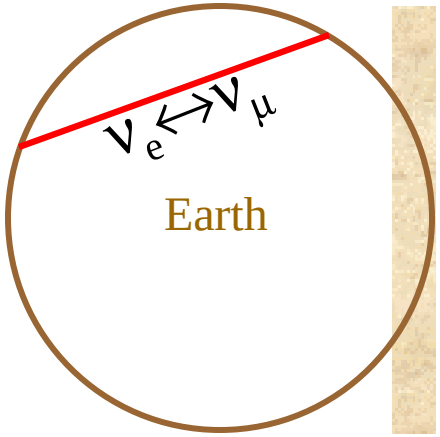
    2) A neutrino oscillation experiment with a ~3000 km baseline

    3) Tau neutrino appearance experiments for atmospheric and LSND Δm^2 values
- Non-oscillation neutrino physics: A dependence, structure functions, polarization.....
- MI Fixed Target program
  - Investigate the measurement improvements that would be available with increased beam intensity

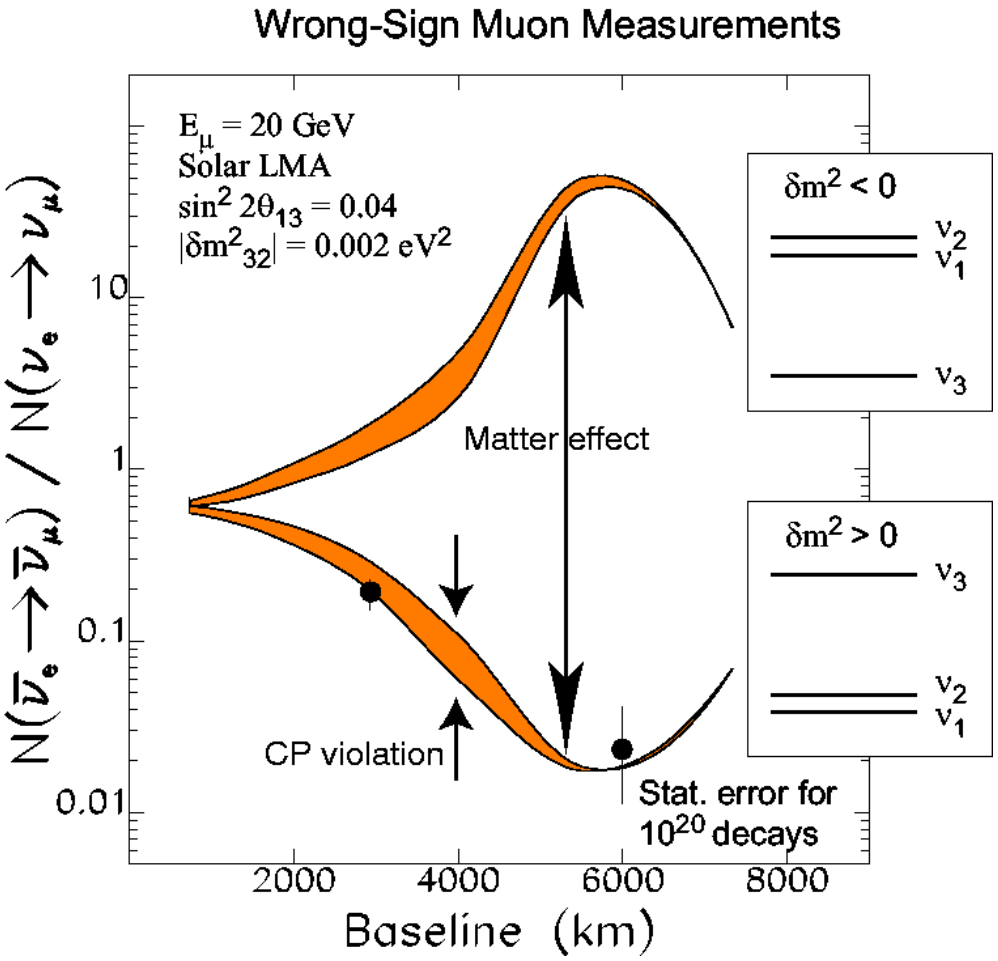
    $\Rightarrow$ What would be the ideal/required intensity for a given measurement?
- Low energy muon/pion facility
  - Investigate the physics potential of a high intensity low energy beam facility
  - Investigate the potential for using this facility for ν-factory cooling R&D
- Collider experiments
  - What is the highest luminosity that the detectors can use?
  - Are there strategies to use higher luminosity for specific physics measurements?
- Other possible areas: neutrons, pbar, etc.

Matter (and ~~CP~~) Effects for $\nu_e \leftrightarrow \nu_\mu$

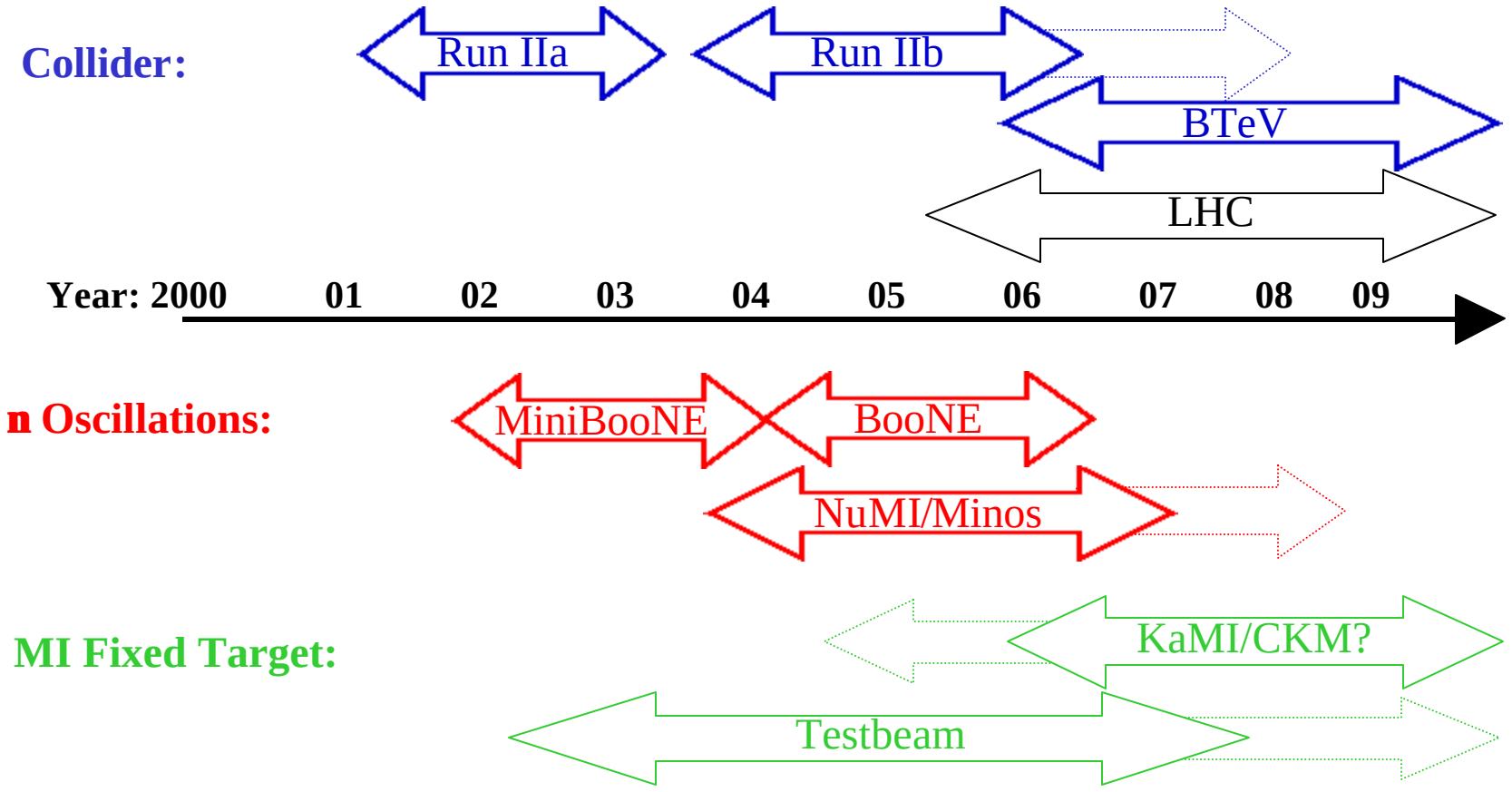
- For long baseline experiments, matter effects change the oscillation formula:
  - $\nu_e\, e \rightarrow \nu_e\, e$ NC and CC
  - $\nu_\mu\, e \rightarrow \nu_\mu\, e$ NC only



- Oscillation probability is modified depending on sign of $\Delta m^2 = m_3^2 - m_2^2$
  - Measure sign of Δm_{32}^2 to determine if $m_3^2 > m_2^2$



Fermilab HEP Program



Neutrino Oscillation Scenarios

- Conventional ν-beams can be used if $\sin^2 2\theta_{13} > \sim 0.01$?
  - Minos upgrade to x4 intensity and/or x2 in mass
  - Long baseline (3000 km) to measure matter effects (sign of Δm^2_{23})?
- Need ν-factory to push $\sin^2 2\theta_{13} < \sim 0.001$
  - Measure $\sin^2 2\theta_{13}$ and matter effects
- If LMA solution or MiniBooNE
  - CP violation measurements possible